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Statement of Work for

Supply and Investment Analysis of
Mobile Alternating Current Power System (MACS)

For
US Army Installation Remote Power Missions

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1.0 **OVERVIEW**.

Mobile AC Systems (MACS) have been demonstrated by the Army since 1999 at various installations and geographical areas. These power systems have been employed at installations such as Ft. Stewart, Ft. Bragg, Ft. Irwin, Ft. Lewis and the Yakima Training Center. The purpose has been to supply electrical power to remote areas of installations where electricity from the local power grid is either not available or not economical.

The objectives of this demonstration program are to:

(a) provide a platform for demonstrating, promoting and understanding the renewable energy technologies as applied to remote energy missions for Army installations applications
(b) demonstrate renewable energy hybrid electric alternatives to fossil fuel generators
(c) reduce logistical requirement for fossil fuel and maintenance of generators

Some of the installation missions for which MACS has been employed are security and lighting, radio repeater and communication stations, water pumping and air compressing, gathering weather data, community relations, technology demonstrations and fairs and tactical, deployed soldier training missions.

2.0 HISTORY

The first mobile electric hybrid trailers were composed of a ¾ ton trailer with a 5kW diesel generator augmented by a 3kW, foldable photovoltaic array with associated battery banks providing a total of about 400 amp hours at 48 volts. A Trace Engineering (Xantrax) inverter was used to convert direct current from the photovoltaic array to alternating current to be used for remote AC electrical needs. The second prototypes featured the same components but with larger trailer (1.5T) and more stored energy capability. The third prototype followed the heavier trailer regimen but added a Bergey, 1kW wind complement. The total kilowatt rating of all trailers demonstrated to date has been a 10kW maximum, ½ of which came from the fossil fuel generator.

3.0 RENEWABLE ENERGY TECHNOLOGIES OF INTEREST and CONCEPT OF OPERATION

The technologies used for this demonstration will be solar, wind and hydrogen. Of these three, hydrogen energy is the focus of this application. Previously, all MACS power platforms have relied on fossil fuel energy sources (i.e. diesel generators) for backup power to the overall system. Back up power is defined as power whenever renewable energy source power from solar or wind is non-existent and that no stored energy is available in the battery bank.

Hydrogen energy in this case will be a three part system, using energy from (1) solar/wind to (2) electrolyze water and then to use the (3) hydrogen from this process to be used as fuel in a hydrogen internal combustion engine (ICE) or fuel cell. Using hydrogen as a fuel will lessen dependency on fossil fuels and will reduce pollution emissions.

4.0 MACS Technical Description

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The following description of the preferred system "component list" will serve as a guideline:

Design Peak Power Demand: 10kW

Safety Components and considerations:

1. System Grounding
   Because this system will operate at voltages greater than 100V direct current and at 120V alternating current, consideration should be given to grounding so that inadvertent shock can be avoided. To this end, a grounding rod should be employed which should be attached to the engine block, trailer assembly or to the inverter(s).
2. Spillage
   As most of the trailer weight will be located over the main trailer axle, the trailer bed should at all times be safety posted (located beneath the front section of the trailer bed) so that 3 points of rest are in touch with the ground at all times. If, in the event of trailer instability (expected when too much weight is distributed to the rear of the trailer platform), consideration should be given to both the hydrogen ICE (or fuel cell) and to the battery banks such that tipping of 45 degrees will not cause neither fuel, lubricant or battery acid spillage.
3. Fire
   A fire extinguisher shall be provided for the MACS having the capability to deal with fire from hydrogen storage or from metal hydride components.
4. Volatile Substance Container Safety
   a. Hydrogen fuel storage shall be appropriately labeled and securely fastened to the body of the trailer and not to the engine nor any electrical component where inadvertent storage tank puncture or inadvertent ignition is likely.
   b. Batteries shall be properly labeled and encased within a box capable of catching any toxic substance spill yet with enough air circulation for proper battery operation.
5. Wind Turbine blade height(s) shall at its lowest point be 8 feet above the trailer bed.

Energy Production

1. 6 kilowatts of photovoltaic (PV) array(s)
   (to minimize volumetric and weight considerations, thin film PV is desired having high energy density characteristics (e.g. watts / kilogram))
2. 1 kilowatts of wind turbine

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3. 5kW electrolysis converter
4. 5 kilowatt hydrogen ICE (or fuel cell)
5. 10 kilowatt power inverter

Energy Storage

1. 1,200 amp hours of energy storage medium will be employed. Consideration should be given to technologies such as nickel metal hydride batteries to decrease weight while simultaneously delivering requisite stored energy.
2. Electrolyzing water to provide the required hydrogen fuel source can be performed in a variety of ways. Significant consideration should be given using metal hydride as the storage medium as this will minimize both the use of high pressure hydrogen tanks and fire hazard.

Mobility

The US Army will provide the required M105, 1.5T (payload) trailer for mobility purposes.

Accessibility

Users of the system must be able to have free access to the fuel cell (or hydrogen generator), fuel storage area, energy storage area, inverter and all receptacles for purposes of everyday use and maintenance. Consideration should be given to the limited access to the M105 trailer from the sides as vehicle height and wooden side panels may interfere with free operation of the principal components.

Data Logger

Appropriate software (e.g. Hyperware) will be installed on the appropriate computing platform and hardware will be installed on the MACS for purposes of data collection and analysis. The following essential elements of analysis will be monitored from data collected from the data logger;

- water level
- temperature
- battery state of charge
- energy coming into the system from solar and wind
- amount of hydrogen produced by the electrolyzer
- amount of hydrogen available for use
- hydrogen genset (or fuel cell) run time (genset on versus genset off)
- amps being drawn from the battery bank to power various loads
- amount of excess power being generated but not being used by the MACS

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Table 1.0 Summary System Components for M105 Trailer

PV Array	Solar energy 6000W array, consisting of an array size not greater than 200’ by 200’.
Wind Turbine Generator	Single wind-turbine capable of 1000W minimum power output.
Engine-Generator and Electrolyzer	5kW (or smaller), 120VAC, 60Hz, 4950W hydrogen generator (or fuel cell) with sufficiently sized electrolyzer.
Battery Bank	Sufficient battery bank modules for a total capacity of ~1200AH.
Battery Charge Controller	Two Outback MX60 maximum power point tracking (MPPT) controllers with 60A, 24VDC output.
Inverter	Sine wave inverter/chargers with a combined output of 4000kW at 120VAC, 60Hz.
Data Acquisition System	Data logger and sensors.

5.0 Mobile Alternating Current System Platform Assembly and Delivery

This project is being done to learn more about renewable energy and the hydrogen conversion process and as a renewable energy teaching tool for the US Army Corps of Cadets at the United States Military Academy (USMA), West Point, New York. To leverage as much experiential learning from this process as possible, the assembly, construction and integration of this effort will occur at USMA. **Delivery will be FOB Destination and all components will be delivered on or before 11 March 2005.**

6.0 Maximum Load Capacity for M105 Trailer (Line Item Number W95811)

The Army M105 trailer should not carry more than 3,000 pounds of payload. Therefore, each and every component from Table 1.0 plus miscellaneous cables, grounding stakes, coverings, fire-extinguishers, etc. need to be considered in the overall planning of the system components for weight prior to installation. Likewise, each piece needs to be considered for volumetric considerations as well.

7.0 Motive Power

The Army M105 trailer requires a minimum of a 2.5T truck or 5T truck to pull it for two major reasons.

1. The air brake connectors on the M105 trailer are only compatible with the air-brake connectors on the trucks mentioned above. Under no circumstances will the M105 be pulled with a HMMWV. The HMMWV uses electric brakes and therefore the brake connection is not compatible.

2. Weight of 3,000 pound payloads require a minimum pulling power of a 2.5T truck or a 5T truck.

8.0 Integration and Transport

All components of each version will be securely mounted within the volume of the trailer. The wind turbine mast and the PV array will be disassembled and secured for transit. All batteries, controls and displays will be mounted in lockable metal enclosures. A dust cover provided with the Army supplied M105 trailer will protect the equipment during transit. The maximum payload of the M105 trailer is 3000 pounds.

9.0 Detailed Description of Notional Components

Enclosures

Battery, AC and DC enclosures are all of the same size and construction. Only the faceplates are changed to accommodate different controls, displays and connectors. The 22.25 x 24.25 x 18 inch enclosures are fabricated from 0.125-inch aluminum and are powder coated Olive Drab inside and out. Floor and top vents are sheltered from direct splashing and are covered with cleanable dust filters. A lockable faceplate cover protects the controls and prevents unauthorized entry into the enclosures. The enclosures can be stacked using the stacking plates, or mounted to the trailer. See drawing 293-13-020 for additional details.

Enclosure mounts and electrical connectors are configured to allow quick field exchange of any battery, AC or DC enclosure in the event that repairs are necessary. The enclosures are mounted on a steel chassis that is, in turn, mounted to the trailer. The chassis allows for vibration isolators between the trailer and the system components, helps distribute the loads imposed by the wind turbine mast onto the trailer and allows the system to be readily adapted to other trailer designs.

Battery Enclosure

Each battery enclosure contains two 12V, 255AH Concorde PVX12255 absorbed glass mat (AGM), sealed, maintenance-free batteries. The batteries are connected in series, forming a 24V, 255AH battery module operating at a 20-hour discharge rate. The faceplate contains a 175A circuit breaker to isolate the batteries during shipping and storage and to provide short circuit protection. A Link 10 display in each battery module shows battery state of charge while in operation and while in storage, facilitating battery maintenance. Locking connectors on cables provide the interfaces with other components.

Up to four battery modules can be paralleled in a system, depending on the weight capacity of the trailers. The 4-module system in the M105 will provide approximately 16 hours per day of silent running at 50% Depth Of Discharge (DOD). If required under special circumstances, the 4-module system can provide over 24 continuous hours of silent running if the low cutoff voltage of the battery bank is adjusted for an 80% DOD. However, repeated use at 80% DOD will substantially reduce the battery lifetime.

Each battery enclosure assembly should weigh approximately 410 pounds. Metal lift handles are provided to allow use of a lifting pole or forklift.

DC Enclosures

The DC enclosure is stacked on top of the AC enclosure. It contains the PV and wind charge controllers, wind turbine diversion load, DC load controller, circuit breakers LED and LCD status displays, and data acquisition system. Connectors for each input and output are unique, preventing improper connections. A DC outlet provides 20A of unregulated DC power.

A maximum power point tracking PV charge controller device is recommended because it will follow the load better and optimize the solar energy usage. (Technically, the load following device optimizes the output of the PV array under varying sunlight and temperature conditions.)

Likewise, a controller is also needed to regulate the diversion load of the wind turbine to prevent excessive charging when the batteries are fully charged. The excess energy should be used in the following sequence (1) provide energy to the electrolyzer to produce hydrogen, (2) provide energy to the battery bank (to minimize on time of the hydrogen generator (or fuel cell) and if necessary (3) dissipate any excess wind energy in a resistive heater.

Another controller will be required to provide a low voltage disconnect for the DC outlet to prevent excessive battery discharge. This function is served by the inverters in the AC section of the system (below).

AC Enclosure

The AC enclosure may contain the inverters, the associated circuit breakers, and utility input, engine-generator (or fuel cell) and electrolyzer inputs and load output receptacles. Each enclosure may contain two sine wave inverter/chargers, providing a combined 8000W, 120VAC, 60Hz output. The inverter/chargers provide DC to AC conversion, battery charging and an AC transfer switch. The AC loads may be connected through four duplex, 15A and 20A GFCI, locking receptacles.

Under normal conditions, the engine-generator may be started and stopped automatically according to the battery state of charge and electrical load. It should also be configured to be started manually, stopped by depressing an emergency stop button, or operated in a mode that bypasses the inverters.

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10.0 Prototype Model

The US Army installation at Fort Lewis, Washington and Yakima Training Center have the most recently build prototype MAC systems (without the hydrogen component). A photo of the unit is herein included as well as M105 (trailer) schematics.
Photo of US Army, M105 (trailer), Mobile Alternating Current System;
Ft. Lewis, Washington

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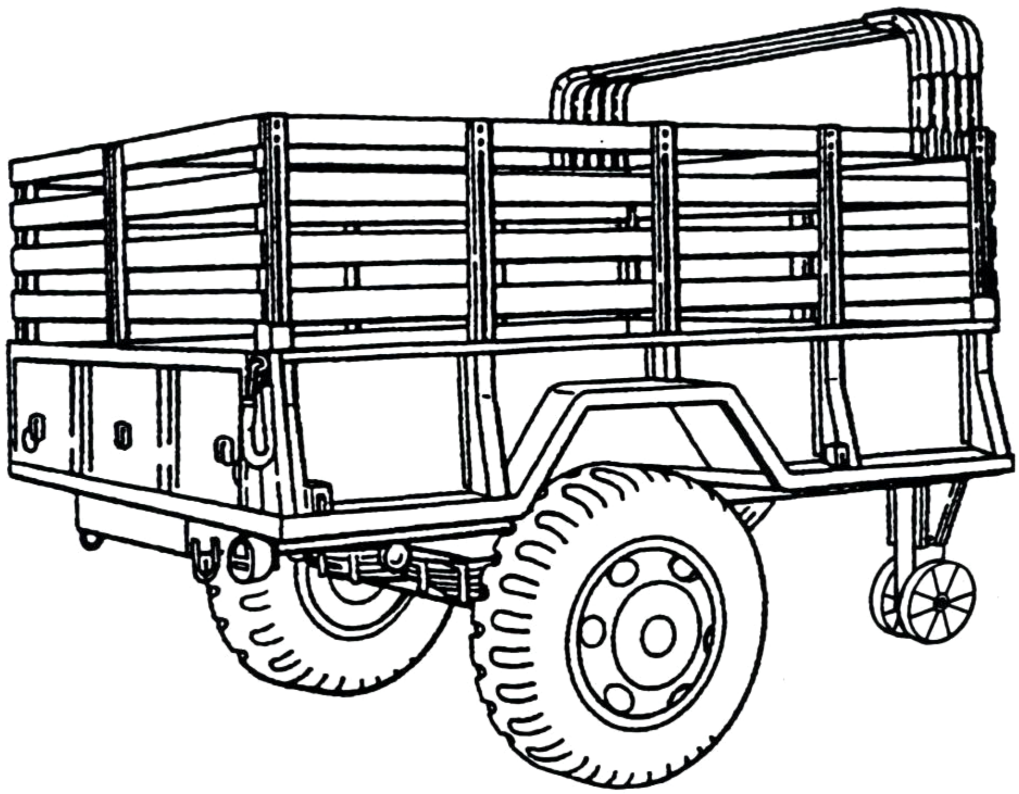
M105 (trailer) schematics

TRAILER, CARGO: 1 1/2-TON, 2-WHEEL, M105A2



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The trailer, cargo, 1 1/2-ton, 2-wheel, M105A2, consists of the M103A3 chassis, trailer, with cargo body mounted and is used to transport general cargo. The cargo trailer series M105A1, M105A2, and M105A2C are used to carry a maximum payload of 3000 pounds (1362 kg) cross-country and 3000 pounds (1362 kg) on highways.

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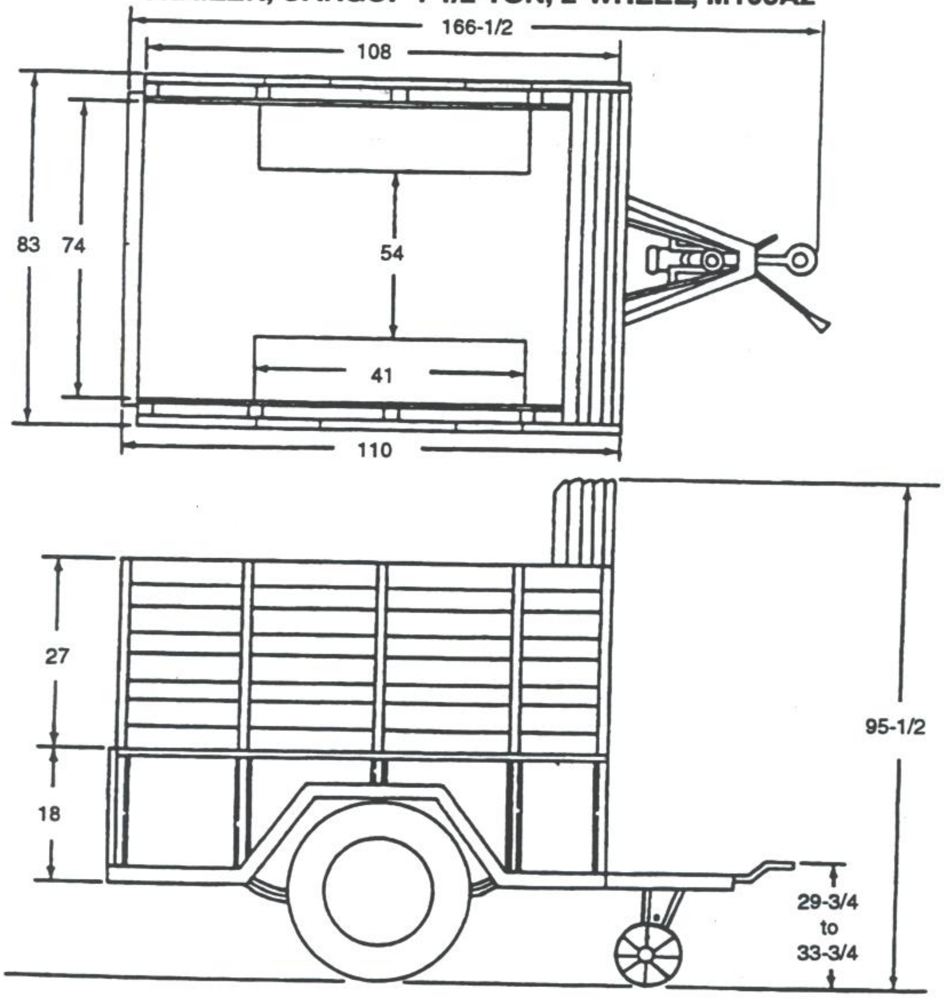
TRAILER, CARGO: 1 1/2-TON, 2-WHEEL, M105A2



VEHICLE CHARACTERISTICS

P/N: 8358993
NSN: 2330-00-141-8050
LIN: W95811
SSN: D064-01
TM: 9-2330-213-14&P
Curb Weight: 2750 lb
Weight Distrubtion:
Lunette Eye 230
Axle 2520
Landing gear 310
Axle 2440 lb
Maximum Weight (including body and with payload evenly distributed):
Loaded
Lunette 365
Axle 5385
Total 5750
(Referenced weights are for information only.)
Fording: Submersible to top of chassis for 15 min.
Lunette: Coupler - drawbar, ring
Landing Gear: Retractable and adjustable, offset swivel, with landing wheels

Axle: Tubular
Springs: Flat leaf, 2-1/2 in. wide x 48 in. long, 12 leaves
Auxiliary spring: 5 leaves, 7411042
Wheels: Disc, offset
Size 7.5 x 20, 6-3/16
Tires: Pneumatic 9.00 x 20
Style A, 8-ply NDCC
Tubes: Pneumatic, group 2 9.00 x 20, ZZ-1-550
Brakes: Service installation
Drum size 15 x 3
Actuation: Air/hydraulic
Brakes: Parking installation
Drum size 15 x 3
Actuation: Manual
Electrical System: Installation 24 volts
Maximum Towing Speed:
Loaded 15 mph
Highway 50 mph
Tiedowns: 3 each side of frame